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13. ABSTRACT (Maximum 200 words)

Work by Prof. Fujimoto and his collaborators is summarized here

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ANNUAL PROGRESS REPORT

Grant#: N0001491-J-1956 R&T Code: 5400067fel04

PRINCIPAL INVESTIGATORS: Dr. James G. Fujimoto and Dr. Christopher Stanton

INSTITUTION: Massachusetts Institute of Technology and University of Florida

GRANT TITLE: Femtosecond Studies of Carrier Dynamics in Compound Semiconductors

REPORTING PERIOD: 1 January 1993 - 31 May 1994

AWARD PERIOD: 1 March 1991 - 31 March 1994

OBJECTIVE: The objective of our program is to develop and combine state of the art femtosecond measurement techniques with advanced solid state theoretical techniques to study carrier dynamics in semiconductors.

APPROACH: This program is a collaborative effort between investigators at the Massachusetts Institute of Technology and the University of Florida. Experimental efforts at MIT focus on the development and application of new femtosecond techniques for measuring ultrafast processes in compound semiconductors and devices. Studies include investigation of both nonlinear index and absorption and gain dynamics in bulk semiconductors and devices. The work at the University of Florida focuses on developing new approaches for studying ultrafast carrier dynamics of carriers in semiconductors and predicting transient behavior as it impacts on device performance. Investigations use full band structure calculation combined with techniques for numerically solving the Boltzmann and quantum transport equations for both electron and hole distributions. Because the dynamics of excited carriers in semiconductors is extremely complex, detailed theoretical studies are required to extract fundamental information on carrier dynamics from experimental measurements or to predict transient behavior.

ACCOMPLISHMENTS (last 12 months): During the past contract year, we have developed a new technique for performing independent multiple wavelength pump and probe measurements in waveguide devices. This approach is based on the use of a Kerr lens modelocked Ti:Al_2O_3 laser combined with spectral pulse shaping techniques and heterodyne detection. This technique is extremely powerful because it permits the energy relaxation dynamics of carriers to be studied in waveguide devices. We have performed the first studies of femtosecond carrier heating and spectral hole buring in strained layer InAs/AlGaAs laser diodes.

Studies at the University of Florida have focused on theoretical techniques for interpreting experimental results and unifying experiment and theory. We have developed band structure calculations for strained layer systems and a Runge Kutta numerical technique for solving a symmetrized Boltzman transport equation to predict measurements of pump and probe gain and absorption dynamics in InAs/AlGaAs strained layer diodes.

We have also studied the theoretical electronic, optical and transport properties of Si quantum wires, using a second nearest neighbor tight-binding calculation coupled with a coupled multi-band Boltzmann transport equation. These investigations are motivated by the recent observations of high efficiency luminescence in porous silicon and its implications for visible display technologies. We find that in the quantum wires, the band structure becomes pseudo-direct, and when excitons are included in the calculation, the oscillator strengths can become comparable to GaAs. Transport calculations show that electron and hole mobilities increase linearly with cross sectional wire size.

theoretical approaches which are pursued in this program can be used to provide fundamental information about the physics of excited carriers in semiconductors and how they impact on electronic an optoelectronic device performance. Strained layer devices are especially interesting because they extend the wavelength range of laser diodes and reduce the hole band degeneracy to yield lower threshold laser operation. Studies of carrier relaxation mechanisms have a direct bearing on gain and absorption dynamics in laser diodes where perturbations of quasithermal carrier processes produce changes in gain and index in high speed modulation.

WORK PLAN: During the continuation of this contract, we will continue studies in strained layer InGa/AlGaAs materials and devices. Our objective will be to develop an understanding of both nonlinear gain and index effects from an experimental as well as a theoretical perspective. The implications of fundamental carrier dynamics processes for high speed device behavior will be investigated. We will also extend studies to other materials systems at different wavelengths including the GaInAsSb/AlGaAsSb materials in the 2 micron region as well as II-VI materials. Working in collaboration with investigators at the Vanderbilty Free Electron Laser Center, we will investigate nonlinear index effects in narrow bandgap semiconductors.

PUBLICATIONS AND ABSTRACTS (last 12 months):

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2. D. W. Bailey and C. J. Stanton, "Calculations of ultrafast differential transmission in germanium," Phys. Rev. B, submitted for publication.

3. A. V. Kuznetsov and C. J. Stanton, "Coherent phonon oscillations in semiconductors," Phys. Rev., submitted for publication.

4. G. D. Sanders, C.-K. Sun, J. G. Fujimoto, H. K. Choi, C. A. Wang, and C. J. Stanton, "Carrier gain dynamics in InGaAs/AlGaAs strained-layer single-well diode lasers: Comparison of theory and experiment," Phys. Rev. B, accepted for publication.

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15. E. Westwig, F. Wise, D. Bailey, and C. J. Stanton, "Effects of band-gap renormalization on relaxation of hot electrons studied with 15 fs resolution," International Quantum Electronics Conference (IQEC'94), Anaheim, CA, May 8-13, 1994.

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Workshop on Coherent Optical Intercations in Semiconductors, Cambridge, UK, August 11-13, 1993.

26. C. J. Stanton, A. V. Kuznetsov, and C. S. Kim, "Optical generation and detection of carriers in ultrafast pump-probe spectroscopy of semiconductors," NATO Advanced Research Workshop on Coherent Optical Intercations in Semiconductors, Cambridge, UK, August 11-13, 1993.

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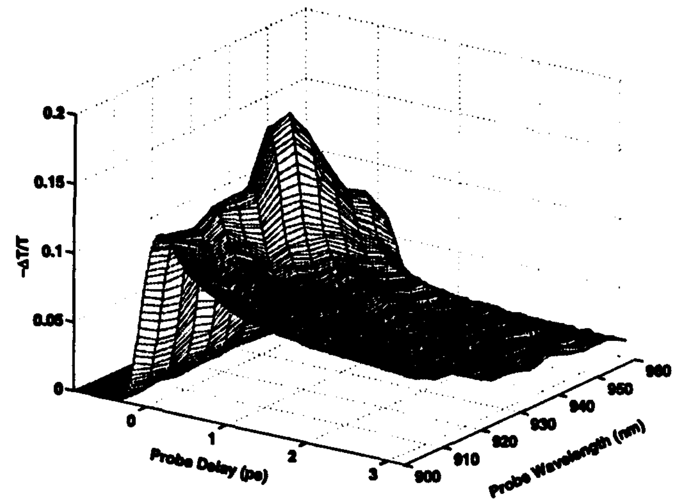
36. C. J. Stanton, "Hot electron effects near the semiconductor interface," 4th Workshop on BEEM, January 25, 1993, Williamsburg, VA.

J. Fujimoto, MIT and C. Stanton, U. Florida



Femtosecond gain dynamics in InAs/AlGaAs diode lasers

FEMTOSECOND STUDIES OF CARRIER DYNAMICS IN COMPOUND SEMICONDUCTORS

Objectives

- Develop and apply new femtosecond measurement techniques for semi-conductors
- Combine experimental and state-of-the-art theoretical studies
- Measure fundamental carrier dynamics processes in semiconductors
- Predict device behavior

Accomplishments

- Developed new multiple wavelength measurement technique for pump probe in waveguide devices
- Performed first studies of carrier dynamics in strained layer InAs/AlGaAs devices
- Calculation of band structure for strained layer QW structures
- Development of theoretical model based on Boltzman transport eq.

Significance

- Combination of experiment and theory necessary to analyze data from transient experiments
- Can directly measure fundamental scattering constants
- Carrier dynamics govern high speed device behavior
- Strained layer systems important because of extended wavelength range and reduced threshold

Annual Report Questionnaire

Principal Investigator: James G. Fujimoto and Christopher Stanton
Institution: Massachusetts Institute of Technology & University of Florida
Project Title: Femtosecond Studies of Carrier Dynamics in Compound Semiconductors

Number of MFEL supported

Papers published in refereed journals: 10 (plus 1 accepted, 3 submitted)
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Number of MFEL supported patents/inventions

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Awards/Honors To PI And/Or To Members Of PI's Research Group (please describe):

J.F. was promoted to Full Professor; J.F. was selected Program Co-Chair for 1994 International Quantum Electronics Conference and Program Co-Chair for 1996 Ultrafast Phenomena Conference.

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